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FISHERIES

Discovery of a spawning ground reveals diverse migration strategies in Atlantic bluefin tuna (*Thunnus thynnus*)

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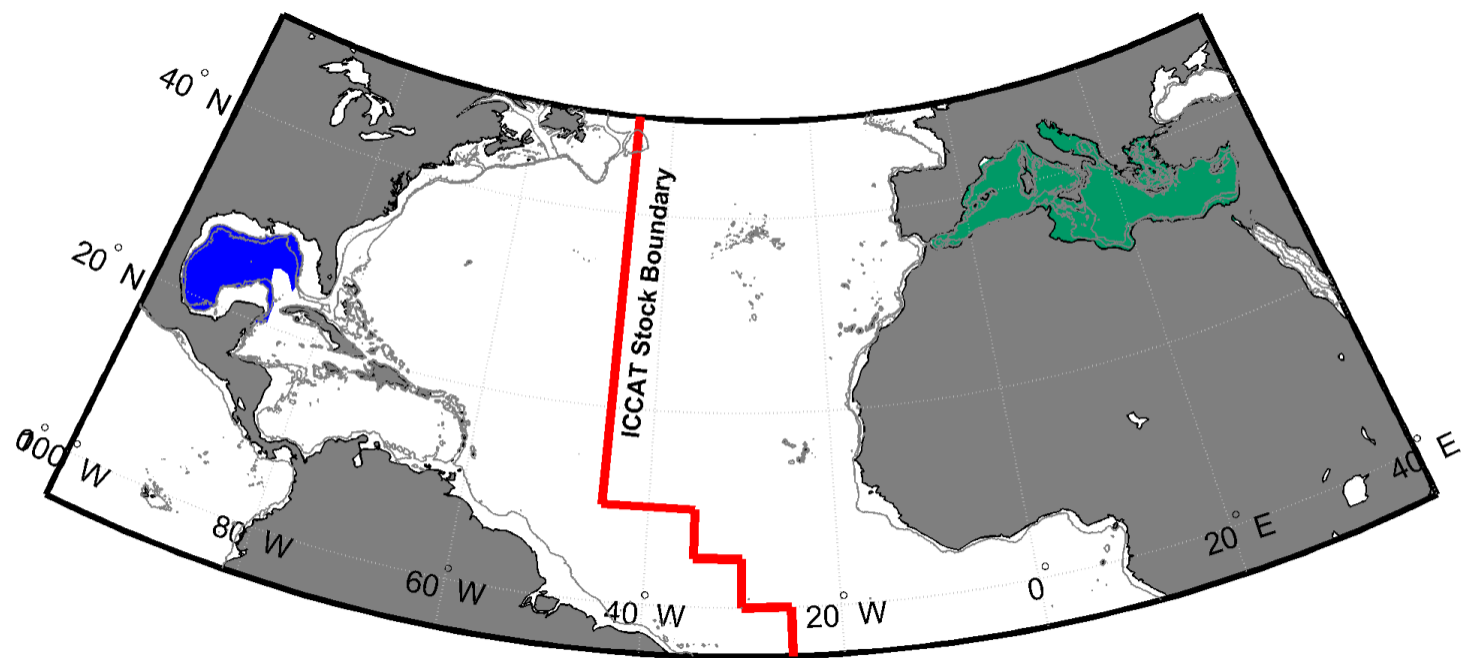
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ICCAT Advisory Committee, 10 March 2016





Current Atlantic bluefin tuna assessments

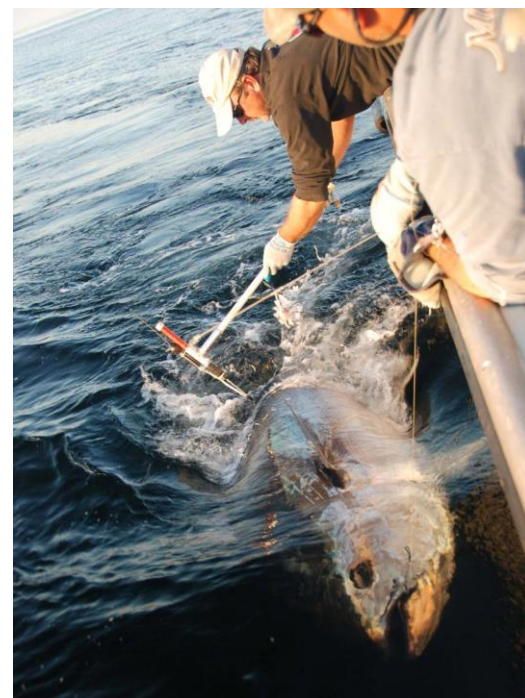
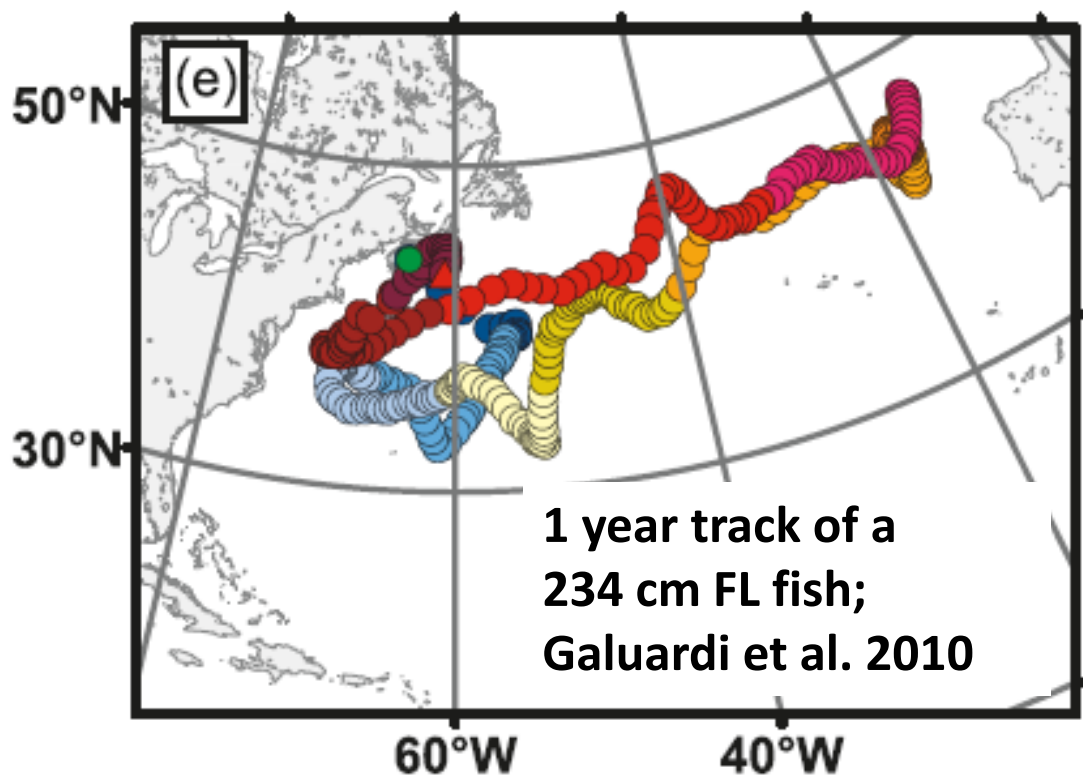
- Assessed as two separate stocks; an eastern Atlantic stock that spawns in the Mediterranean Sea and a western Atlantic stock that spawns in the Gulf of Mexico
- ICCAT boundary used to assign catch and CPUE indices to a stock
- Fish recognized to be cross the ICCAT boundary but this is presumed to occur only for feeding
- Maturity in Eastern Atlantic: Age 4 (115 cm) - A50%
- Maturity in Western Atlantic: Age 9 (190 cm) - “Knife-edge”

Questions from electronic tagging data

Many fish larger than the assumed size at maturity do not visit either the Mediterranean Sea or Gulf of Mexico

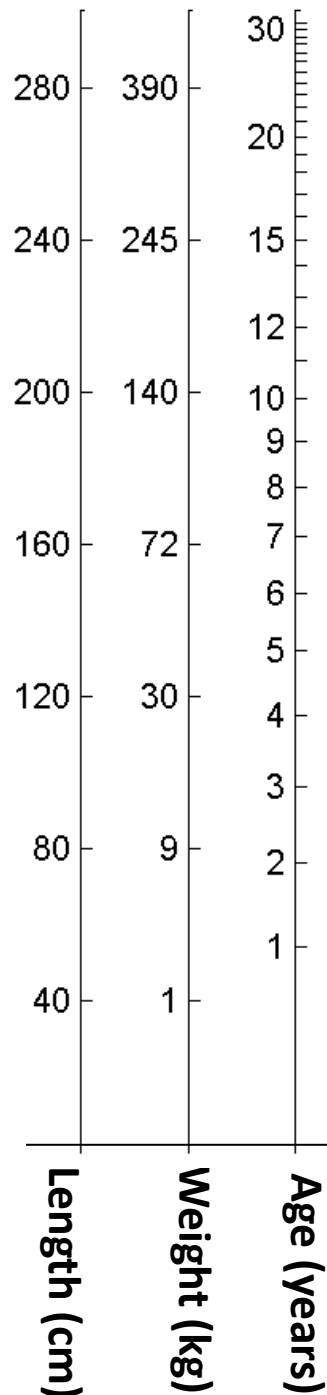
Are these fish not spawning until an older age?
or

Are these fish spawning elsewhere?



Paul Murray Photography

What is the size and age at maturity for western Atlantic bluefin tuna?



≈ 85 pounds
≈ 52 inches
Age 4-5



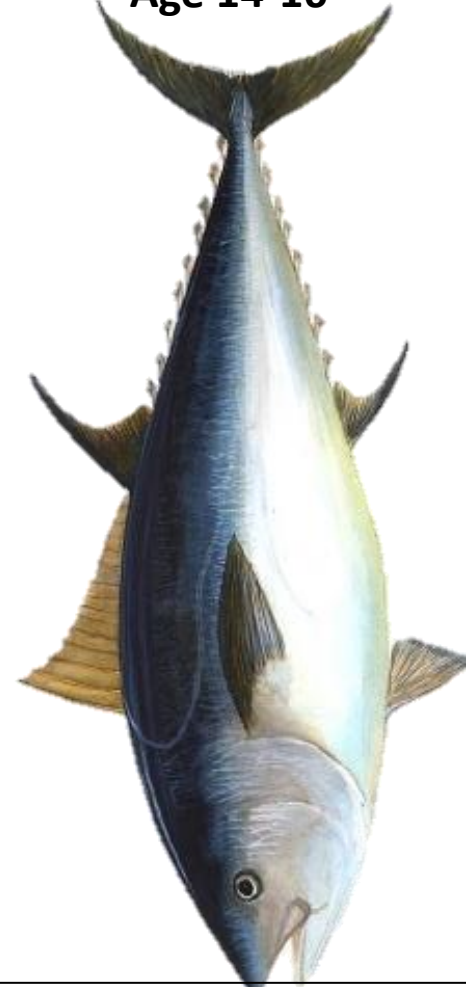
Endocrine,
Macroscopic gonad
examination,
Life History Theory

≈ 250 pounds
≈ 75 inches
Age 9



ICCAT assessment,
Minimum size of
mature fish in Gulf of
Mexico

≈ 550 pounds
≈ 95 inches
Age 14-16



Size structure in Gulf
of Mexico in both
electronic tagging
and catch data

Where else could western bluefin tuna spawn?

There are less numerous indications of a secondary spawning area in the western North Atlantic at the northern edge of the Gulf Stream east of the Middle Atlantic States.

This area is frequented mainly by medium (120-185 cm) sized bluefin, and most of the ripe or nearly ripe fish captured there have been in this size range.

More information on the spawning of these medium-sized bluefin is urgently needed.

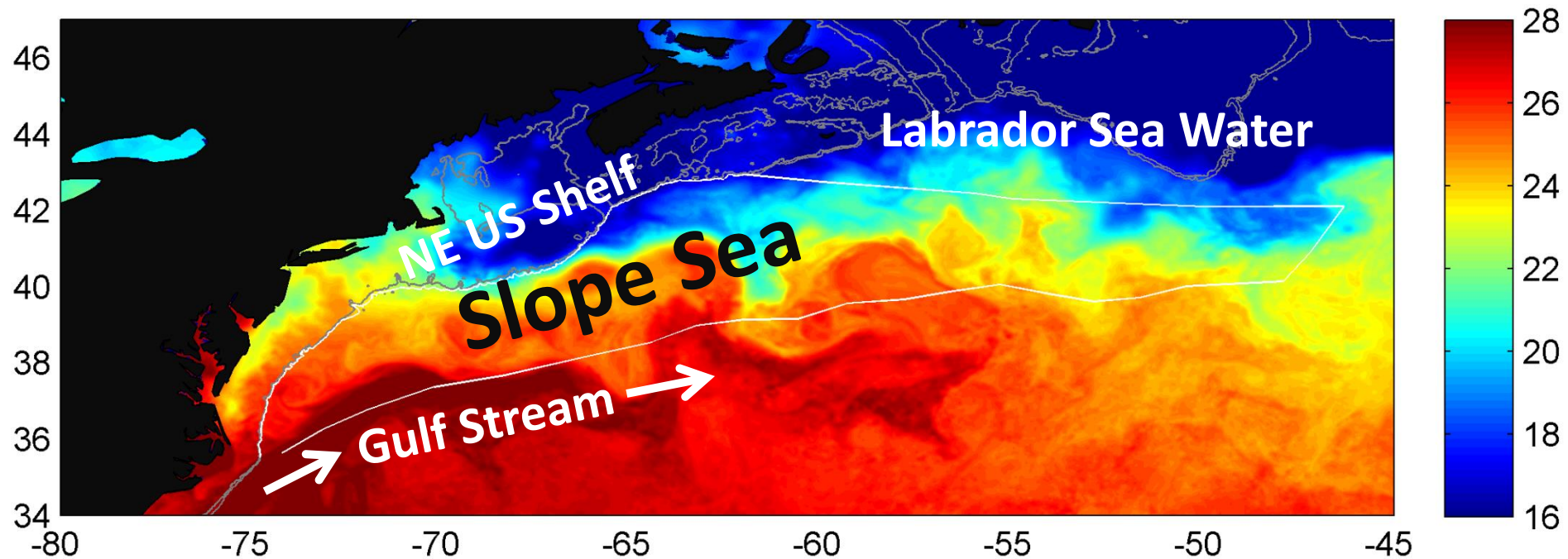
Frank Mather et al. 1973. Col.Vol.Sci.Pap. ICCAT 2: 234-258



Frank J. Mather and Martin R. Bartlett with giant bluefin tuna from Cape Cod Bay, 1958.
Photo by Florence E. Young

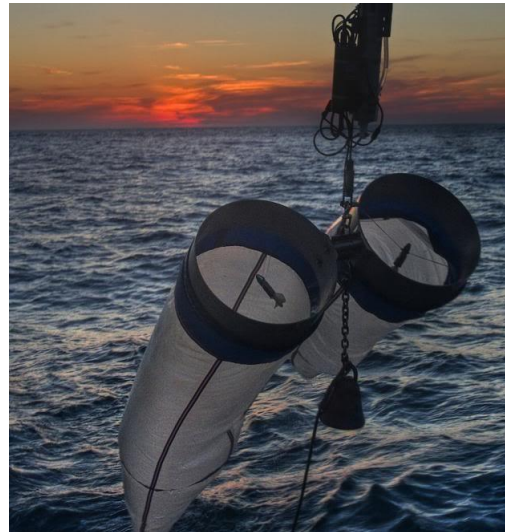
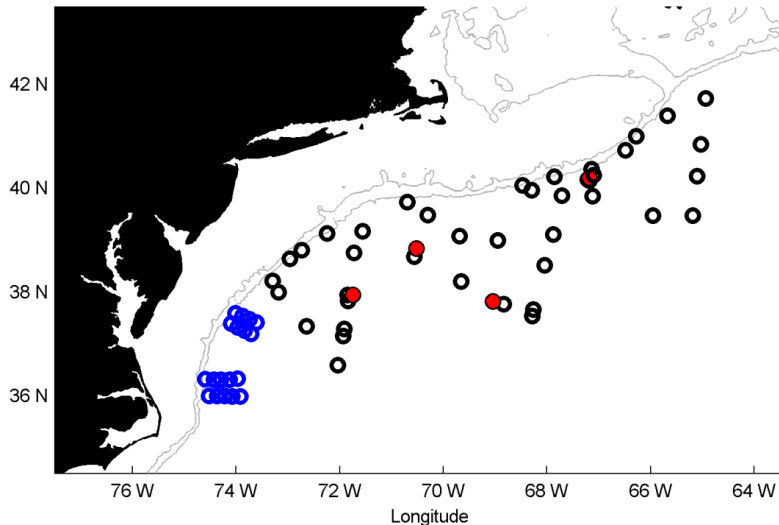
Slope Sea

- Bound by the northeast U.S./Canadian continental shelf, Gulf Stream and Labrador Sea Water (Csanady and Hamilton 1988)
- Characterized by large Gulf Stream meanders and anti-cyclonic rings.
- Similar oceanographic characteristics to Gulf of Mexico bluefin tuna spawning grounds



Ichthyoplankton Sampling

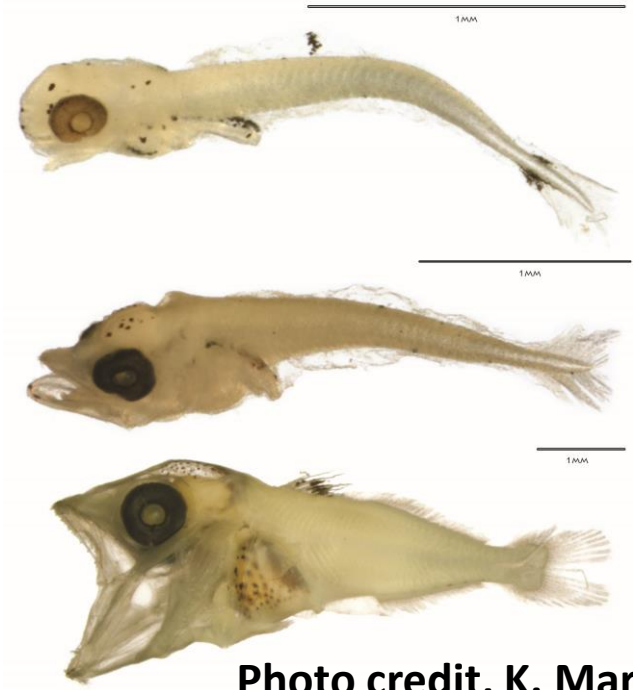
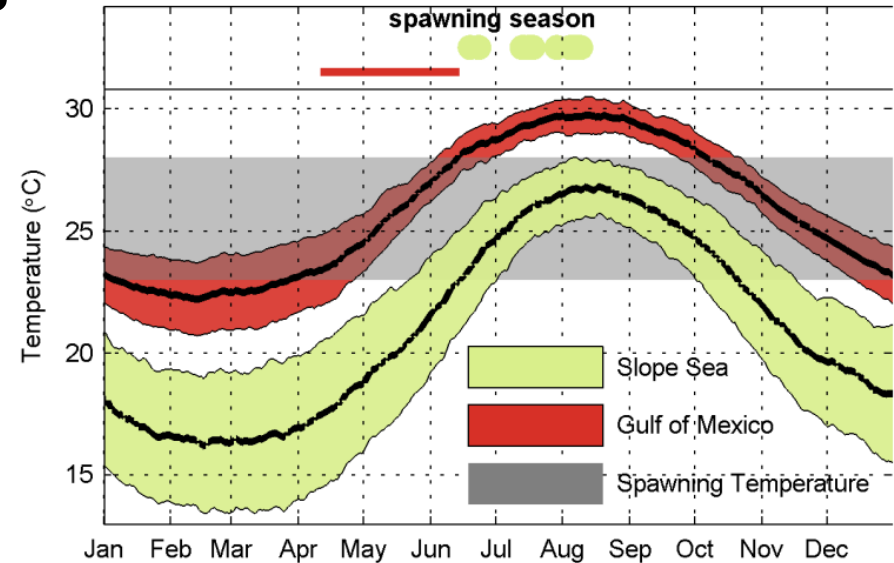
- The collection of larval bluefin is the clearest way to document a spawning ground
- NOAA Northeast Fisheries Science Center monitoring of larval fish abundance restricted to the continental shelf, the Slope Sea is rarely sampled
- Two cruises opportunistically sampled this area in 2013
- These cruises were not looking for bluefin tuna larvae



Bluefin larval collections

- 67 larvae collected from 23 June-8 August; 2 months later than Gulf of Mexico spawning
- Genetics used at two separate labs to confirm the identifications
- Collection numbers comparable to the annual Gulf of Mexico sampling
- Larvae too young to have been transported into the area from the Gulf of Mexico

Temperature cycles and spawning seasonality

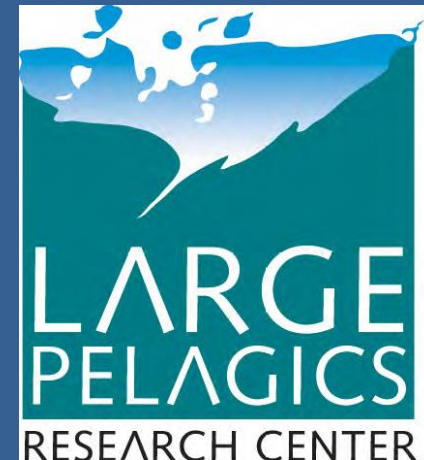
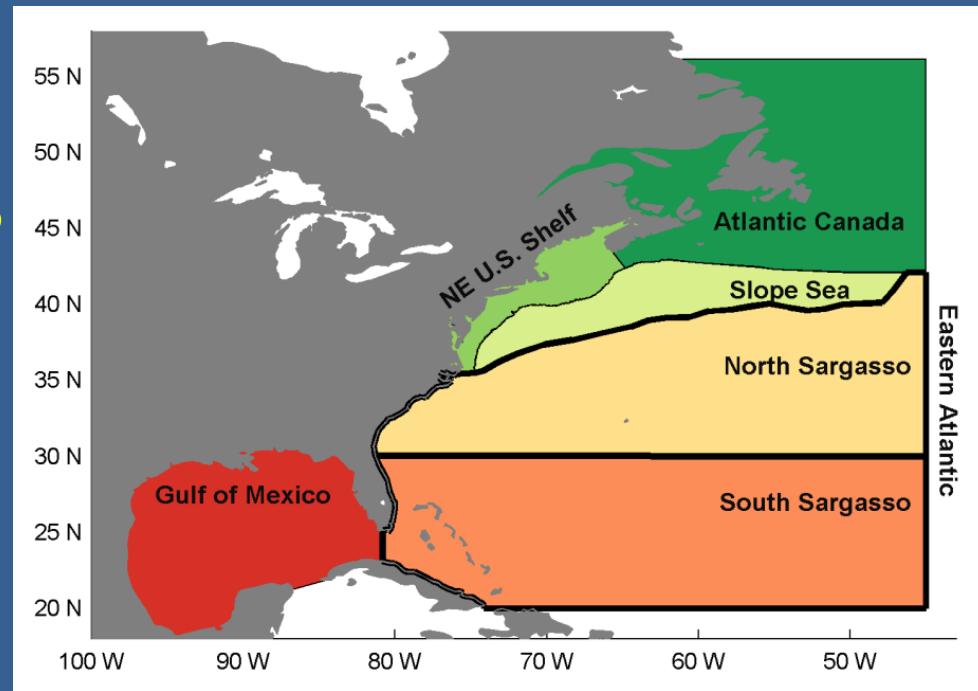


Larval data available in PNAS supplemental material, concurrent oceanographic data at (<ftp://ftp.nefsc.noaa.gov/pub/hydro/>)

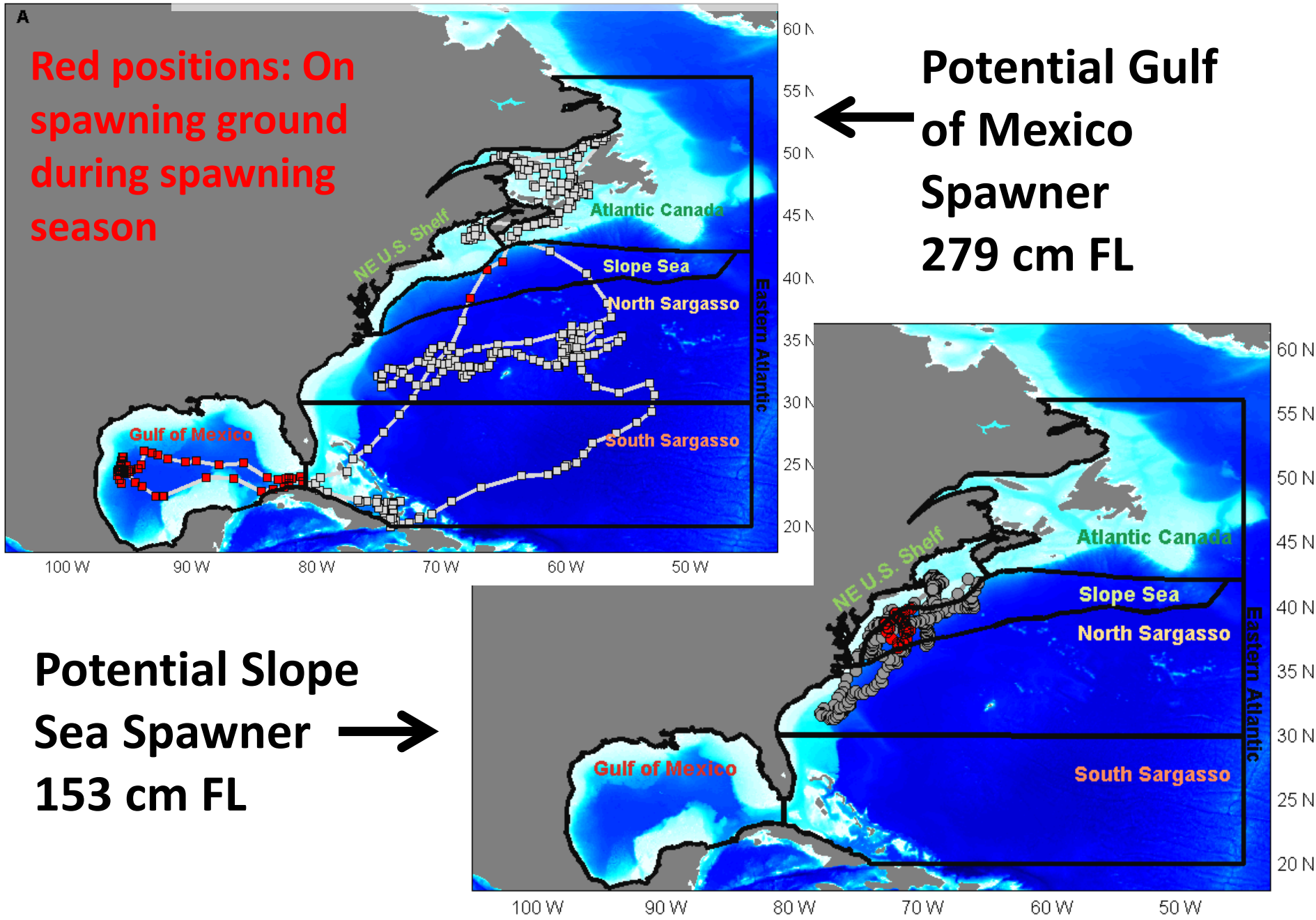
Photo credit, K. Marancik

Evaluating migration patterns

- Used electronic tagging data
- Fish location assigned to 1 of 7 regions for each day of year
- Fish classified as potential Gulf of Mexico spawners if they entered the Gulf of Mexico
- Fish classified as potential Slope Sea spawners if they spent ≥ 20 days in the Slope Sea during the spawning season

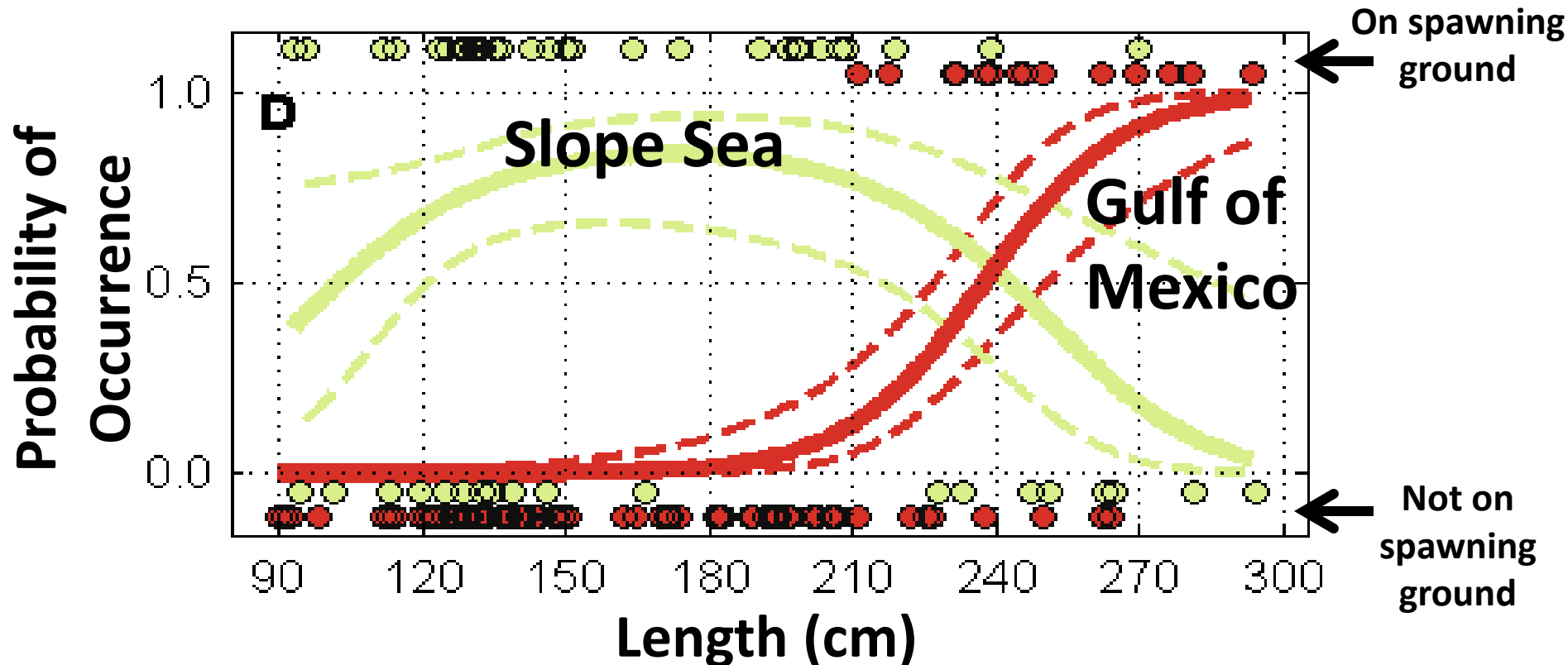


Annual migrations of two bluefin



Spawning ground assignment by size

- Only largest fish enter the Gulf of Mexico (about 50% by 240 cm FL); remarkably consistent with analyses using independent catch and tagging data from the 2000s and from the late-1970s/early-1980s
- Greater than 75 % of fish 133-212 cm FL were classified as potential Slope Sea spawners



Support for a younger age at maturity and size structured migrations

- Macroscopic examination of gonads on the Slope Sea spawning ground in 1957 (Baglin 1976 and Mather et al 1995)
- Microscopic examination of gonads from individuals caught in the Gulf of Maine (Goldstein et al. 2007)
- Endocrine measurements (Heinisch et al. 2014)
- Each dataset has its own limitations, but in aggregate they point to a consistent picture
- **Urgent Need: Direct reproductive sampling on the Slope Sea spawning ground needs to be updated**

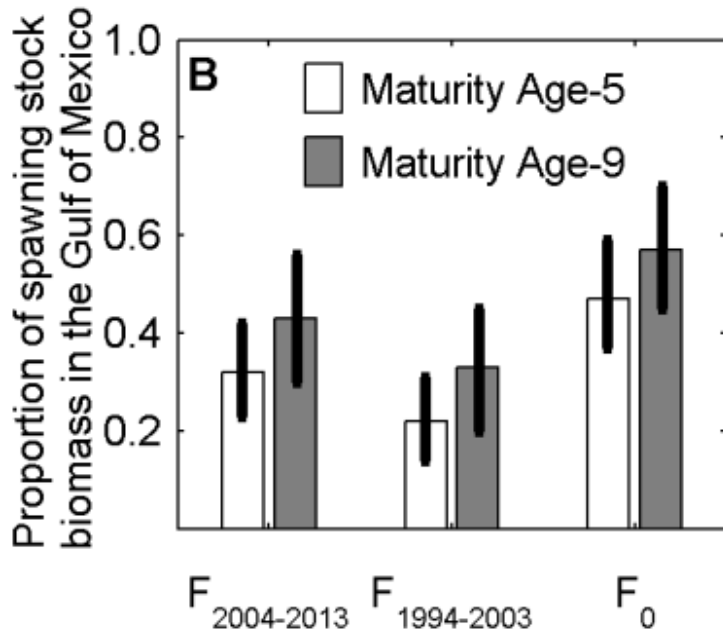
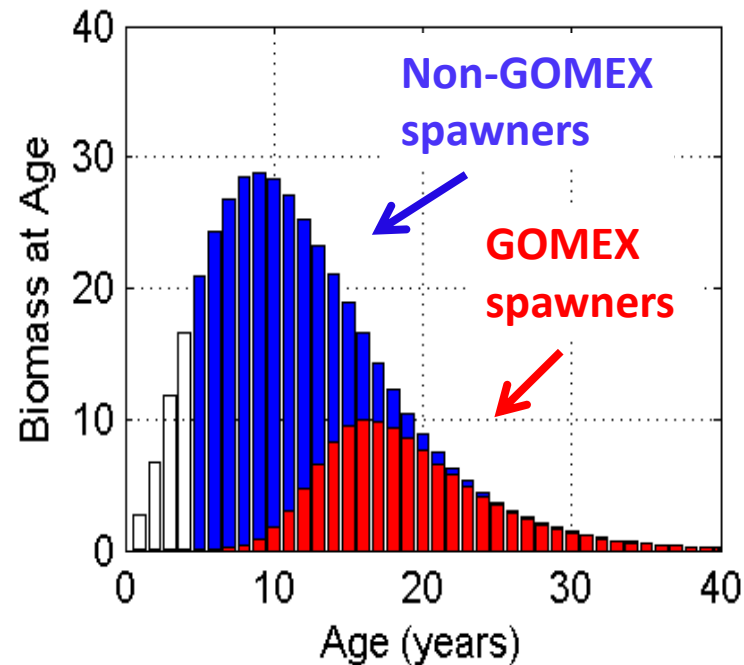
What proportion of western Atlantic spawning occurs in the Gulf of Mexico?

$$\text{Proportion of spawning in the Gulf of Mexico} = \frac{\text{Biomass of fish that migrate to the Gulf of Mexico}}{\text{Biomass of mature fish}}$$

- Use Spawning Biomass per Recruit instead of total biomass
- Requires information on:
 1. Total mortality rates at age (Fishing Mortality + Natural Mortality)
 2. Weight-at-Age
 3. Maturity-at-Age
 4. The Proportion of bluefin migrating to the Gulf of Mexico at age (from electronic tagging data)

Recent F and Age 5 Maturity

- $F_{2004-2013}$
 - Age 4-14 \rightarrow 0.04-0.06
 - Age 15+ \rightarrow 0.076
- 32% of Spawning occurs in Gulf of Mexico



Sensitivity Analyses

- Increased Fishing mortality causes age-truncation and a reduction in the proportion of spawning that occurs in the Gulf of Mexico
- Most scenarios indicate <50% of spawning in Gulf of Mexico

What are the implications of Slope Sea spawning for Atlantic-wide bluefin tuna population structure?

- Phenotypic differences (Maturity, Growth) between Eastern and Western Atlantic spawning bluefin tuna are not clear (as once thought)
- Sampling of all life stages on the Slope Sea spawning ground needed for updated genetic and otolith microchemistry studies
- Slope Sea spawning raises substantial questions concerning how to interpret electronic and conventional tagging data
 - Lack of openness of electronic tagging data (contrary to the standard for oceanographic data and genetic data) hinders progress

Current interpretation of tagging data

- Bluefin have not been recorded visiting both the Gulf of Mexico and Mediterranean Sea
- Fish that eventually end up in the Mediterranean Sea may spend 1-3 years in the western Atlantic to feed
- Spawning site fidelity is near 100%

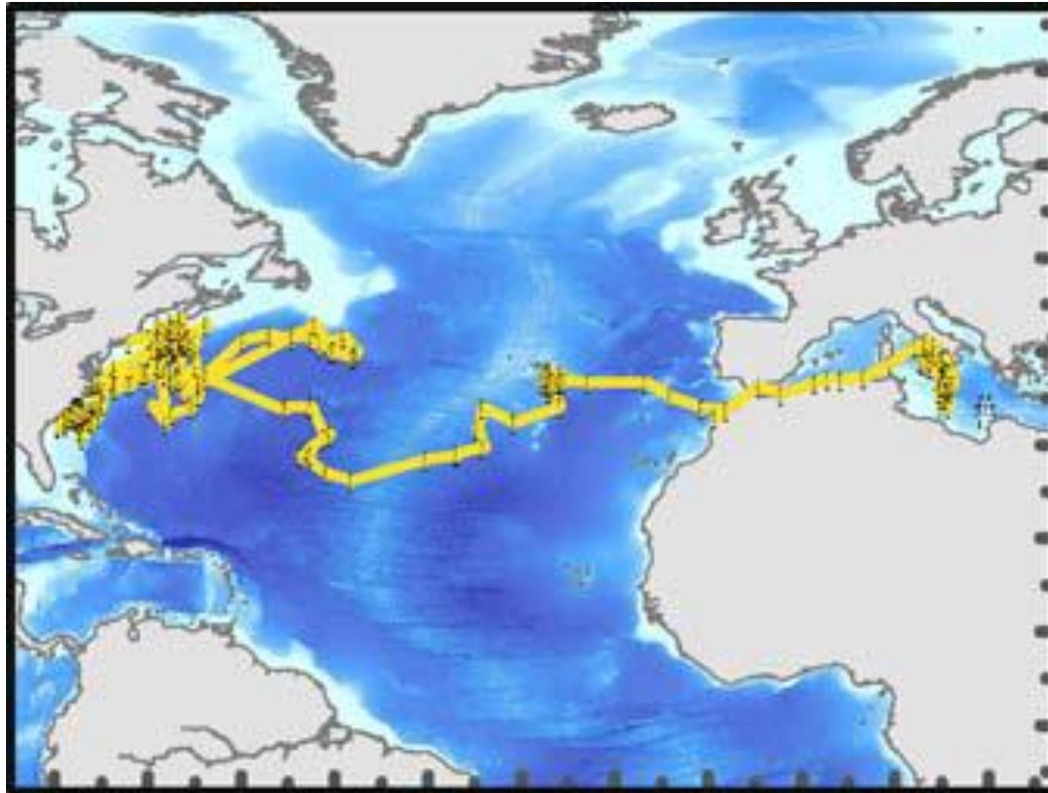
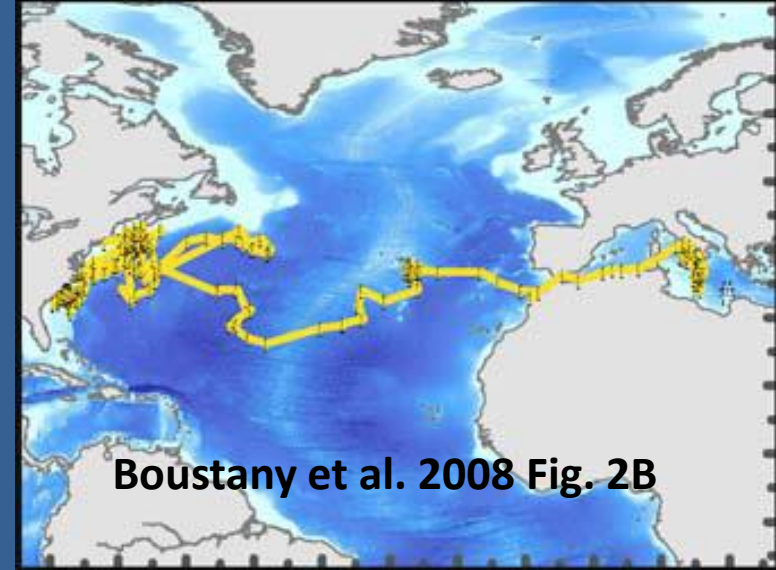


Fig 2b in Boustany et al. 2008. Archival tag LTD1016, tagged January 18, 2003, 209 cm CFL. Recovered off the coast of Libya, June 10, 2006. Assigned to the Eastern Mediterranean Sea population.

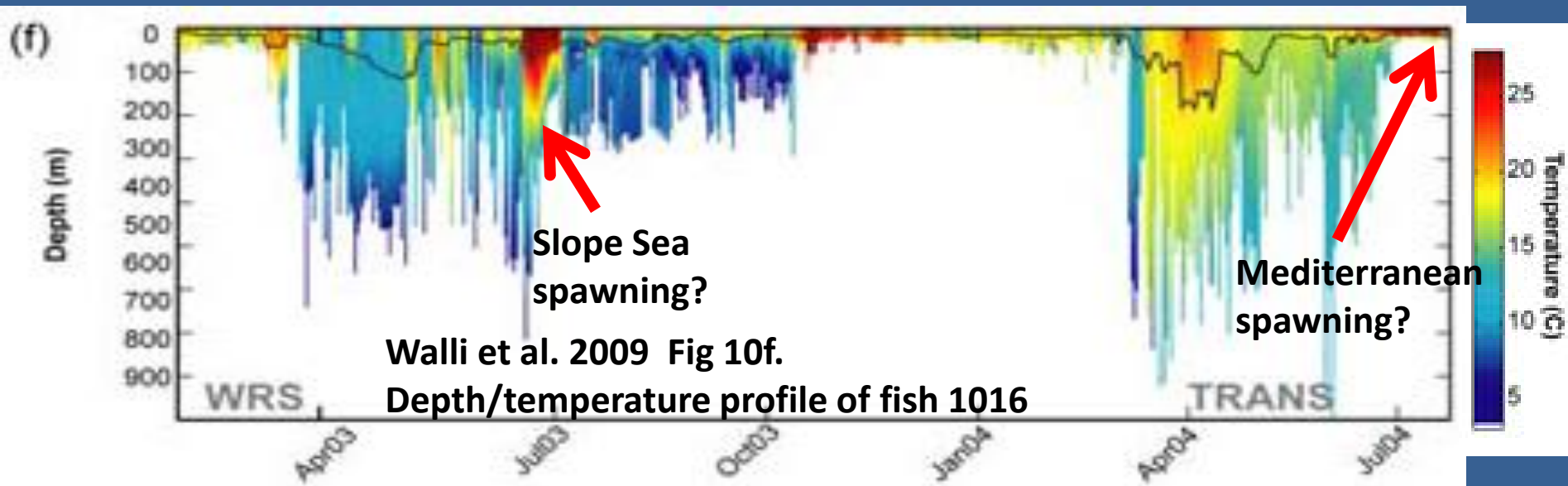
18 Month track shown

Tag 1016

- Late June-Early July 2003 in waters $>24^{\circ}\text{C}$ in western Atlantic; likely in the Slope Sea
- April 2004 undertakes a TRANS-Atlantic migration and enters the Mediterranean Sea in June

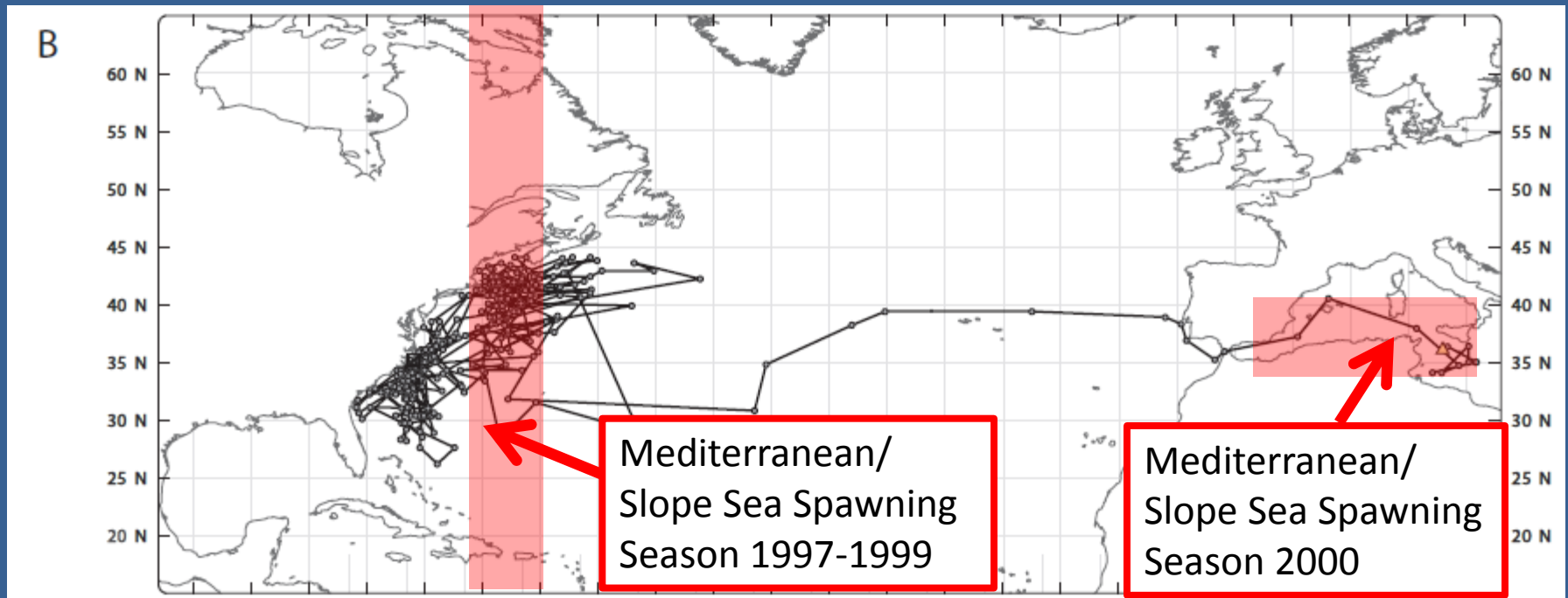


Did this fish spawn in the Slope Sea?



Multi-year archival tag

- Tagged in March of 1997 at 203 cm CFL (197 FL)
- 3 years of western Atlantic residency without visiting Gulf of Mexico
- Recaptured in June 2000 on Mediterranean spawning ground
- Did this fish spawn in the Slope Sea in 1997, 1998 or 1999?

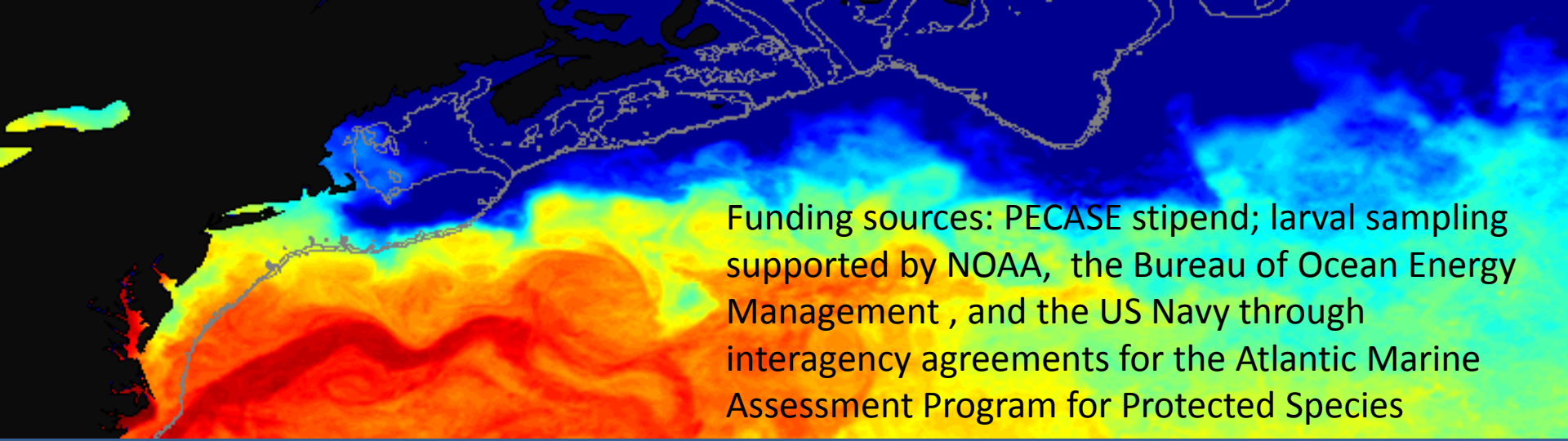


Conclusions

- Larval collections indicate that bluefin tuna spawn in the Slope Sea
- The weight of the evidence points to a western Atlantic bluefin tuna age-at-maturity of around 4-5 years and a majority of spawning outside of the Gulf of Mexico
- Lowering the age-at-maturity and recognizing the broader spawning distribution of western Atlantic bluefin tuna will reduce estimates of the vulnerability of this stock to exploitation and environmental change
- The population structure of Atlantic bluefin tuna may be more complex than is currently assumed

Next steps and urgent needs

1. Dedicated larval survey in the Slope Sea
2. Longline sampling in the Slope Sea to support reproductive studies and collect biological material for integrated studies of population structure
3. Comparative larval ecology work among spawning grounds
4. Better delineation of YOY and Age-1 nursery areas
5. Composite analysis of all electronic tagging data to guide further exploratory larval sampling for undocumented spawning grounds



Funding sources: PECASE stipend; larval sampling supported by NOAA, the Bureau of Ocean Energy Management, and the US Navy through interagency agreements for the Atlantic Marine Assessment Program for Protected Species

Questions and Comments

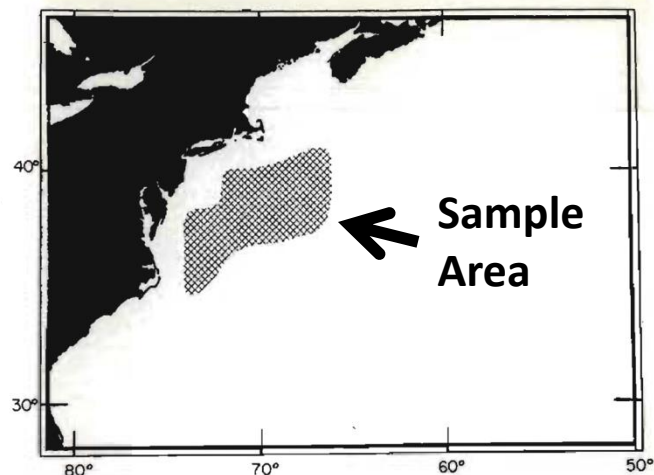


OCEANIC TUNA EXPLORATIONS - LONG-LINE

MV DELAWARE CRUISE 57-5

June 6 - July 5, 1957

CATCH DATA



Sta. No.	Day	POSITION		No. Baskets	BLUEFIN		YELLOWFIN		ALBACORE		SKIPJACK		BIGEYE		BLACKFIN		TOTALS		CATCH / 100 hooks
		N.Lat.	W.Long.		No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	

1	8	40°26'	66°25'
2	9	38°58'	66°26'
3	10	37°45'	66°32'
4	11	37°30'	68°10'
5	12	38°35'	68°12'
6	13	40°04'	68°12'
7	14	39°48'	70°00'
8	23	39°44'	71°23'
9	24	38°46'	71°23'
10	25	38°17'	70°00'
11	26	37°48'	71°23'
12	27	37°02'	70°00'
13	28	36°46'	71°23'
14	30	35°53'	72°35'
15	1	34°40'	73°41'
16	2	37°24'	73°40'
17	3	37°59'	72°25'

TOTALS

<u>Fork Length</u> (cm)	<u>Round Weight</u> (kg)	<u>Age*</u> (years)	<u>Sex</u>	<u>Description of Gonads</u>
156.3	74 *	6	M	abundant sperm; testes much enlarged
163.5	86 *	7	M	moderate sperm
164.0	86 *	7	M	abundant sperm
189.8	132 *	9	F	running ripe
95.4	18 *	3	-	immature
151.2	68 *	6	F	near ripe